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Research & Application of the Drilling Fluid for Water Sensitive Stratum

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Abstract

Modern geological drilling often applied small diameter wire line coring, due to the annular gap between borehole wall and drill rod is very small, so in the drilling of water sensitive stratums, cuttings prone to clogging the annulus, and then result in high pump pressure which damage hole wall and cause downhole accidents. According to rocky and mineral ingredient, water sensitive stratums can be classified: hydrous corrosion, hydrous swelling and hydrous peeling, etc. In the drilling construction of complex stratums, how to choose and use the drilling fluid is very important. This paper analyzes and summarizes two of the most complex and difficult projects which had been encountered in recent years, the stratums were hydrous swelling chlorite stratum and hydrous peeling carbonaceous slate. Dealing with this type of water sensitive stratum, in conjunction with the suitable drilling process, how to select, use and maintain the performance of drilling fluid have been discussed and summarized.

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Keywords: Peat Carbonaceous Slate; Chlorite Stratum; Inhibitive Drilling Fluid; Water Sensitive stratums;

1. Introduction

In petroleum drilling field, shale as typical water-sensitive formation, combined with relevant technology, oil and gas well drilling adopt strong inhibitive drilling fluid system. But, usually geological drilling hardly met the pure shale, generally stratum with high clay content. Each shale has different characteristics resulted from mineral components. Relative to petroleum drilling field, the borehole annular gap is small because geological drilling

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generally use wire line coring, flaked debris resulted from hydration dispersing is prone to black the gap, and cause high pump pressure, and then borehole collapse, bit jamming and other serious hole accidents should happen.

Considering the problems above, in this paper, two of the most complex and difficult drilling projects that had encountered have been analyzed, which are Hongqiling nickel mine with a large segment of water sensitive chlorite stratum, in Jilin Province, and Zhouqu gold mine with peat sedimentary carbonaceous slate, in Gansu Province. Furthermore, selection and application of drilling fluid in the two difficult projects had been summarized. There are two kinds of explanations for hydration mechanism: one is surface hydration, other is permeating hydration. Surface hydration depends on charged condition of crystal layer surface, and type and state of adsorption cations, etc. Permeating hydration is that permeating pressure difference results from salt concentration difference between stratum fluid and drilling fluid makes water molecules move from low ion concentration fluid to the high. The basic solution to drilling fluid in water sensitive stratums is to ensure concentration balance between stratum liquid and drilling fluid.

In the nickel mine project at Hongqiling Jilin province, there is a chloritization altered fracture zone as fragmental clay which easily happen hydration expansion under influence of water. Using conventional mud is difficult to achieve ideal wall protection effect [1], and easy to cause pump choking up and hole wall collapse and etc. in drilling process, at last the drilling cannot continues. The gold drilling project at Zhouqu Gansu province, over 150 m peat deposition carbonaceous slate had been encountered during drilling construction, which presented crushed shape and fine granular. When the stratum is in contact with water, its strength sharply falls, and chipping and peeling, etc. would happen, which would cause a variety of downhole complex situations.

2. Choosing Drilling Fluid for Chlorite Stratum

During the 2011 ~ 2012 winter and spring season, the temperature was as low as -30℃ on nickel mine drilling project site at Hongqiling Jilin province. During drilling construction, protecting hole wall in fractured zone is the main problem, among which the chlorite altered fracture zone is the most difficult problem to overcome in geological drilling field. This is because the chlorite altered fracture zone has strong water sensitivity which using common low solid-phase or non-solid phase drilling fluid is very difficult to achieve the desired effect of protecting hole wall, plus low temperature has remarkable effect of increasing viscosity, makes the drilling fluid low-liquidity and instability, protecting hole wall cannot be further guaranteed.

2.1. Choosing Drilling Fluid System

- In Hongqiling nickel mine area, there were four holes had been abandoned, which took Sichuan Huafeng Drilling Engineering Co. LTD a painful cost. The mining exploration borehole is designed about 1300m deep, where 0~23 m is topsoil, 23~260 m is water sensitive altered amphibolite, 260~1200m is altered, loose and strong water sensitive stratums which soapstone, chlorite and hornblende-limestone appear irregularly and alternately, below 1200m is stable granitic gneiss. Construction difficulties focused on altered chlorite zone. Dealing with water sensitive stratums, "dry drilling" can be used, which no water need to pump while drilling, but, for drilling a deep hole , it is high risk and labour intensity, low efficiency. In order to enable rope core drilling goes on smoothly, KP copolymer low solids mud, double polymer mud, PAB solidfree mud, vegetable gum mud, low solid sulfonated mud had been tried. But, all of them failed to effectively inhibit hydration swelling of fracture zone, which resulting in hole's wall collapse and pump blocked, furthermore, the borehole cannot be swept down to the bottom. Even though repeatedly cementing, the hole's wall stable result is still not satisfactory. Along with the temperature was very low, although the laboratory experiment performances of the drilling fluid was good, due to the harsh construction environment, drilling fluid performance was hard to be guaranteed. Therefore, to select a new suitable drilling fluid system had to be rethought.

To select a drilling fluid system, in addition to the hole's wall protection, a good resistance to low temperature should be considered. Hole's wall protection should consider mud inhibitory and pressure balance, because there was a lot altered stratum, as chlorite, soapstone. Chlorite as a of water sensitive stratums, a hypersalinity drilling fluid should be considered. To deal with scaling and sloughing of soapstone, mud must balance the stratum pressure,

so it is necessary to properly increase mud density. Current drilling fluid systems include solidfree drilling fluid system and low solid drilling fluid system.

A solidfree drilling fluid developed from low solids drilling fluid is a kind of mud which adds some chemical treatment agents. Vegetable gum is a kind of natural plant polymer. Solidfree mud has been widely used in complex stratum geological exploration, and is environmental drilling fluid. Low solids drilling fluid which three based fluid of halogen salts, formic acid salts and organic alcohol, and low clay content formed stable colloidal solution through protective colloid effect [2], its use key point is in a protective colloid in useful solid (clay). Due to poor hole's wall cementation in complex stratum, appropriately increasing solid density of drilling fluid is useful, appropriate content clay helps form a good mud cake. Apart from strengthen wall building property of mud and increasing relative density of mud, compared to solidfree drilling fluid, the important thing is more easily controlling water loss of low solid drilling fluid, in addition, while drilling using high density drilling, its configuration and maintenance is easier than solidfree drilling fluid. So, the system should have strong inhibition, high salinity and high density, low temperature resistance. Through reading a lot of conferences and a plentiful compared experiments, drilling water sensitive stratums chooses saline drilling fluid by comprehensive consideration. High content saline drilling fluid not only can effectively reduce penetrating hydration, but also has good resistance to low temperature [3].

2.2. On-site Application and Maintenance of Saline Drilling Fluid

Although a saline drilling fluid has excellent performance, but its configuring and maintaining were relatively difficult. To configure a saline mud, the first step is to hydrate bentonite in advance. Experiments demonstrated that bentonite's resistance to salinity was poor, with adding NaCl in mud, the electric double layer is being compressed, potential drops and hydration film be thinning, dispersity of clay particles and water loss of mud is decreasing, water loss can experimentally reach more than 60mL, and then the performance of drilling fluid is very unstable. From the following two points, these problems of mud can be solved.

(1)To add high-quality clay, a higher yield of clay can be ensured, and the difference between surface properties of clay particles and rock powder (including low quality clay) has been enlarged, which is in favour of selective flocculation. To adopt high quality slurry and to carry out adequate hydration would be improve the stability of fully hydrated clay, which is very important for the suspension stability of weighting materials as barite. Appropriately increasing density of mud helps to balance ground pressure, and reduce the influence caused by hydration expansion of water sensitive stratums.

(2) Additive of high density brine mud mainly use salt-resistant sulfonated agents [4], such as SMP, SMC, sulfonated asphalt SAS, etc., which have fair dispersity, at same time, some strong dispersion diluent, as FCLS and sulfonated tannins (SMT) should be used cooperatively. Field application verified that the mud had good low temperature-resistant fluidity, strong stability, low viscosity, low water loss, specific gravity suitability (mud density can be adjusted using barite), On and strong inhibitory effect to green clay. The construction efficiency was greatly improved relative to the previous. Property of the formula mud was shown as Table 1.

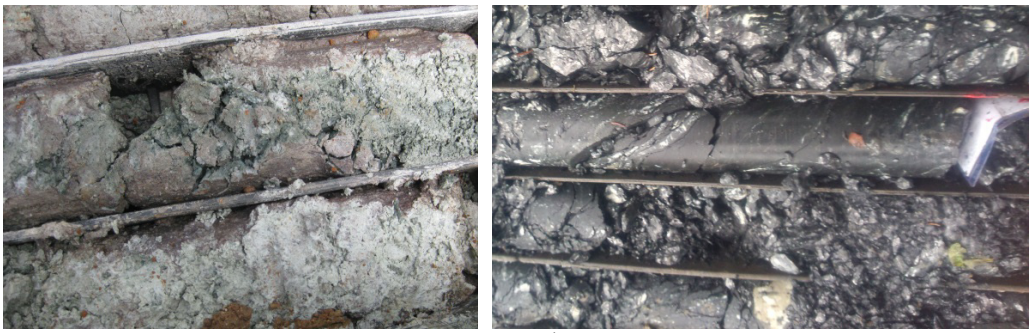
Table 1 Property of the Formula Mud

Formula	Density (g/cm^3)	Filtration (ml)
Nv + 2%NaOH + 3%SHR + 15%NaCl + H_3BO_3+0.3%HT	1.12	4.2

3. Choosing Drilling Fluid for Carbonaceous Slate

April 2013, hard difficulties had been met in Zhouqu drilling project. Formations in the region give priority to brown yellow and grey sandstone slate, limestone and black carbonaceous slate. Slate is a metamorphic rock which is low grade metamorphic rocks metamorphosed from clay, siltstone or slightly acidic tuff, and has significant platy structure. In the mining area, there is mainly sandy slate and carbonaceous slate with limestone. These slate and limestone are integrated, occasionally including no more than 10cm quartz veins. The low metamorphosed carbonaceous shale slate is relatively fractured, partially high oxidated, and 1-5mm particles. The formation is a

main metallogenic belt of the mine area, and a point of key coring and difficult construction. Most of rock's drillability is 8-10 degree. In addition, carbonaceous shale and peat deposition irregular exist, rock's intensity dramatically decreased when wet. With the borehole's depth increasing, using rope coring, the smaller annular gap is, the bigger drilling construction difficulty is, the higher requirement for drilling fluid is.



a b

Fig. 1 (a) Chlorite Alteration; (b) Carbonaceous Slate

3.1. Choosing Drilling Fluid for Carbonaceous Slate

This drilled stratum has plenty of clay minerals, when wet in mud, the hole wall's clay will absorb water, and swelling, dispersing. For water sensitive and stripping stratums, the penetrating hydration should be minimized, which is reducing water loss and enhancing mud salinity. Being different to chlorite stratum, carbonaceous slate is more fractured, high oxidizability and lower coefficient of linear expansion. Its drilling problem is mainly hydration stripping, poor cementation, cementation and hole wall protective of drilling fluid must be improved.

According to the above requirements, test mud formulas are shown as followings:

1#: 3% sodium bentonite +1% CaCO3 +2% SM;

2#: 3% sodium bentonite +1% CaCO3 +1% SM +0.75PAM +0.75%PAN +0.3% NH4-HPAN;

3#: 3% sodium bentonite +1% CaCO3 +0.1% FA-367 +0.1% XY-27 +0.4%L-cmc;

4#: 3% sodium bentonite +1% CaCO3 + +1% PAM +0.5% PAN +0.3% smp;

5#: 3% sodium bentonite +1.5% CaCO3 +2%KHm +2% SAS +1.5%PAM +0.3%PAN +1.5% NH4-HPAN+2% S-1.

Table 2 Test Formula Mud Performance

Formula	Funnel viscosity(*s*)	water loss (mL)
1#	32	8.6
2#	30	8
3#	24	8.2
4#	23	7.2
5#	25	4.2

Through soaking experiment, swelling time of carbonaceous slate respectively is 5 #> 4 #> 2 #> 1 #> 3 #:

1# has a good viscidity, but low inhibition and less strength after swelling;

3# has a good encapsulating ability, but also less inhibition and short swelling time;

4#, 5# is ok;

5# mud is optimized from the 4#, and has better rheology.

Taken together, potassium-base polymer drilling fluid can be used as basis mud. Of which calcium carbonate is rarely used as a treating agent, but it is not only inexpensive but also has a good plugging effect had been experimentally found. It can improve mud cake quality, a strong inhibitive ability to clay hydration, while K+ mosaic effect can play a role in stabilizing hole's wall.

3.2. On-site Application and Maintenance of Potash Polymer Drilling Fluid

The Topsoil is mainly composed of loess and limestone particles, and the rock formation is unitary, a low solid drilling fluid can meet the drilling requirements.

A construction difficulty and key point of the total core recovery is drilling the peat carbonaceous slate. This layer is sometimes a small particle of clay or interbedded with carbonaceous slate which low intensity with higher argillaceous ingredient. The slate is fractured, easy to swap blocks and to stick. But the intensity of peat carbonaceous slate dramatically declines after wet. Once drilling speed is too fast, those peeling cuttings without cracking will be stunk in the under reamer, and then easily lead to pump choking up. Once the pump pressure increase, the hole wall's stability will be broken. Through field experiment and application, the optimized drilling fluid formula is as the follows:

(1)Base mud

Base mud: bentonite, caustic soda, soda ash and proper calcium carbonate, the base mud is as much as possible hydration before using.

(a) Bentonite content is 1.5%;

(b) Using caustic soda, controlling the PH of base mud in about 9;

(c) Dosage of Soda is about 5% of bentonite;

(d) Dosage of Calcium is about 1%.

(2) Treating agents

Treating agents of glue solution can be configured separately, it is convenient for replenish. Main treating agents used are: potassium humate, asphalt, potassium polypropylene, Potassium hydrolysis polypropylene shine, cellulose, S-1 and etc. When dispensing adhesive solution, at first adding diffluent agents, then adding insoluble agents. Formula 6# treating agents are S-1 + KCl + KPHP + SP + (x-1 + EZ), of which X-1 and EZ are optional agents, whether it should be used or not depends on stratum properties and drilling fluid viscosity.

During the site construction, the followings had been used: (1) Finely dispersed drilling fluid: NV-1 + SM + CMC ; (2) Low solids drilling fluid: NV-1 + cmc + cellulose + fluid loss agent + +NH4-PAN + SM, etc.; (3) Non-solids salty mud: salt + k-PAN + SM + KHm; (4) Polymer non-solid drilling fluid: SM +k-PAM+ NH4-PAN ; (5) PAB special mud (good flushing ability, hard configuration and maintenance); (6) Potassium polymer drilling fluid. Field application test that polymer drilling fluid has a long-term property of maintaining the stability of hole wall.

A brief analysis had been made on which mud and its performance maintaining on a hole section where had downhole accident:

While in 190m depth of a hole, using C6 power head drill rig, drills to carbonaceous mudstone and fractured carbonaceous slate, drilling fluid is NV-1 + SM + cmc, pump choking up and bit bouncing was happening. So, when cleaning hole up to the casing, drilling fluid was adjusted to NV-1 + cmc + caustic fluid loss cellulose + k-PAN+SM, the mud viscosity is 30s, torque is basically stable. While drilling to around 228m depth, pump pressure is increased appear again, cleaning hole is difficult. And then, the mud was replaced by a potassium polymer mud, after a long time the hole's wall was stable, until the last final hole smoothly.

4. Mud cooperating with Drilling Technique

Since water-sensitive peeling stratum is thick, while drilling the formations, numer of rock powder is larger than usual, to keep the hole clean and to maintain mud properties, controlling solid phase must be carry out. During project construction process, the all-in-one machine of desilter and desander produced by Beijing Institute of Exploration Engineering had been used to control solid phase of mud. Further, mud testing instruments should be configured on site, pay attention to add relevant mud material and maintain mud's performance and stability. Requirement on mud performance is shown as table 3.

Table 3 Maintaining Mud Performance

Formula	Funnel viscosity (s)	water loss (mL)
6#	22-29	3-5

Usually, a drilling engineering is complex and systematic. During drilling complex stratum, in addition to excellent drilling fluid, drilling tools can select and use semi-core tube, imported high quality clamp spring and spring seat; drill bit select and adopt 12-14 degree diamonds, in consideration of rock's high drillablity and reducing fragmentation volume of rock, the drill bit's diamond use small particle size of diamonds. And to reduce core shaken and broken, it is necessary to use drill bit with ladder matrix face; to reduce core wear by the drill bit, the length of bit inner gage can be decreased; to avoid core erosion by mud flow, bottom spray bits should be used. On occasion, according to mud flushing requirement, the outer diameter of bit should be increased.

Drilling operations should be carried out according to the following three measures, only through cooperating together, high drilling efficiency and satisfactory construction results can be gained.

(1)Three of low drilling parameters: low rotate speed, low weight on bit, low pump output volume. Low rotate speed and weight on bit is mainly in favour of reducing vibration. Low pump output volume need to be calculated using plastic viscosity of mud and diameter and drilling tools, in order to avoid turbulent flow erosion of hole's wall.

(2) If using bottom jet drill bit, the clearance of spring seat and inner matrix of drilling bit should be adjusted to near zero.

(3) For completely loose, fine particle layer, to do appropriate dry drilling an extruding can ensure cores do not fall off, force when a roundtrip drilling is over, sometime it is necessary to control roundtrip drilling footage.

5. Conclusions

Chlorite and peat carbonaceous slate are stratums with high clay content, and are easily hydrated and dispersed. So, while drilling water sensitive stratums, the common point is using a drilling fluid with strong inhibitory and low water loss, in order to reduce osmotic hydration of formations. However, chlorite has high montmorillonite content, and high linear expansivity which could easily result in borehole shrinkage, apart from reducing mud water loss, the drilling fluid density and low temperature fluidity must be suitably control. As to peaty carbonaceous slate, it has relatively low linear expansivity, loose and poorly cemented, and its ground pressure is not too large, in addition to reducing water loss, the key of drilling fluid is increasing the bonding force between particles of the hole wall, which result from reinforcing cementing property of drilling fluid using strong cementing treatment agent (such as asphalt) and improving mud cake quality through adding plugging material.

In summary, a common solution to drilling water sensitive expansion stratum is the following:

(1) Reducing surface hydration and osmotic hydration;

(2) Selecting suitable cementitious material according to stratum properties;

(3) According to the hole's situation, if the drilling fluid balances stratum pressure is confirmed. For complex water sensitive stratums, apart from configurating and maintaining drilling fluid performance, a suitable drilling process is necessary, in order to obtain an ideal drilling effect.

References

[1]Chen Wei, Li Yunzhe, Li Wenbin. PAB no solid phase fluid in the stratum of chlorite Wall drilling crushing effect [J]. Jilin Geology, 2010, 12.
[2]HE Bing Xin, Wu Xiaoming, Hu Yule. research and application of thick water-sensitive stratums strong inhibitory mud [J]. Geological Science and Technology Information, 1999, 06.
[3]Dai Guozhong, SUN Shuai, Liu Leiyang, Chou Chengwei, Yang Jun. Polymer-based drilling fluid without solid experimental study [J]. Changzhou Institute of Technology, 2011, 02.
[4]Ken Zhiyang, Luo Chunzhi, Ye Shijun Yuan Junwen, Yang Shujun. Saturated brine drilling fluid system Foam Application [J]. Yangtze University (Natural Science Edition) Polytechnic volumes, 2007, 06.